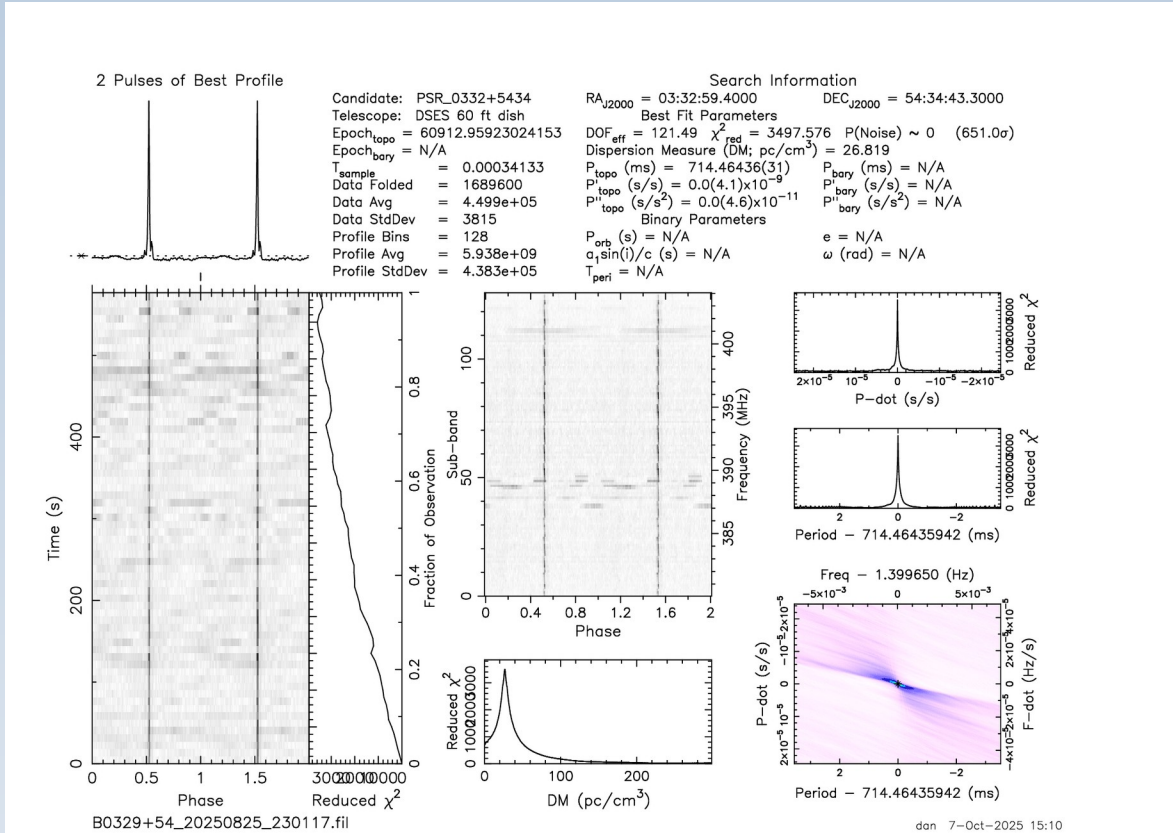


Fishing for Pulsars: Mission Planning



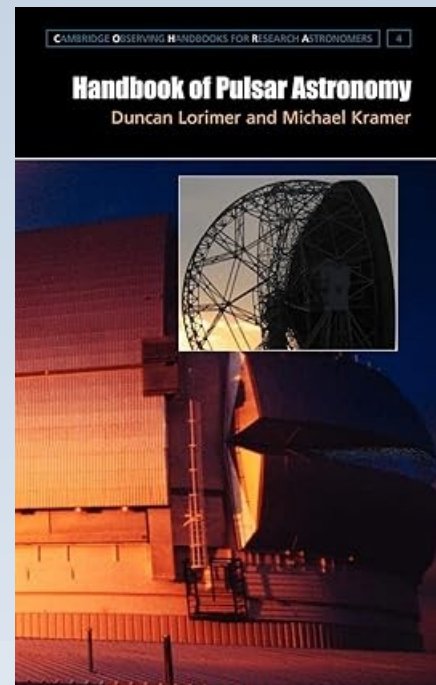
April, 2026

*Deep Space
 Exploration Society*

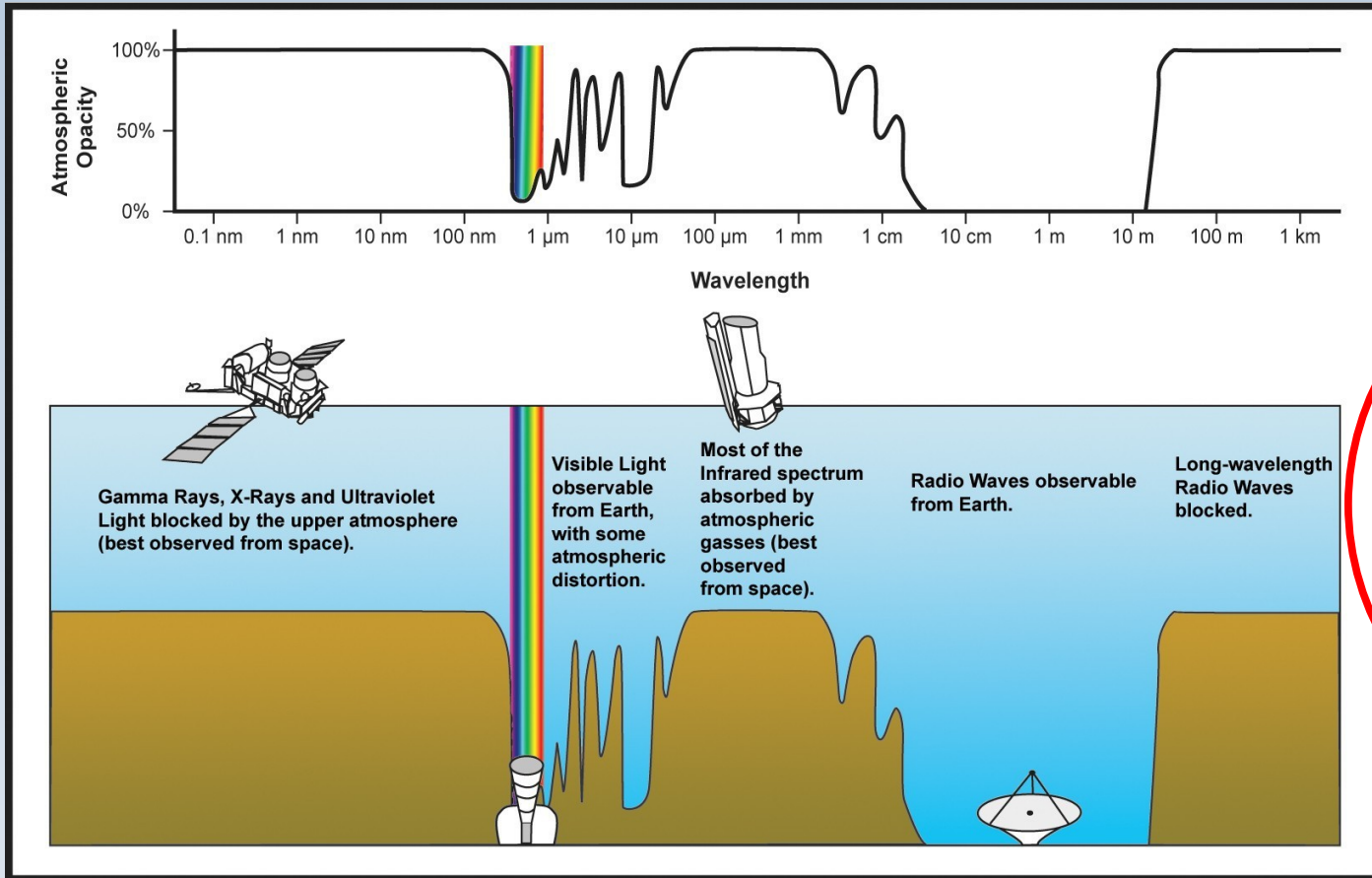
Outline

- Pulsar astronomy fundamentals
- ATNF psrcat, Murmur and DSES catalog
- Frontiers to explore
- Parameters for data collection

Reference: “Handbook of Pulsar Astronomy,”
Lorimer and Kramer, 2005, Cambridge



Atmospheric Window for Radio Astronomy



The atmosphere is transparent to frequencies from 5 MHz to 30+ GHz

RFI sources include:
External – Sun, FM radio, mobile communications, nav radar, air traffic control, LEO satellites, ham radio

Internal - consumer electronics (Wi-Fi, BT, cell), control room equipment, lights, utilities, pedestal

Goal: minimize RFI; maximize SNR

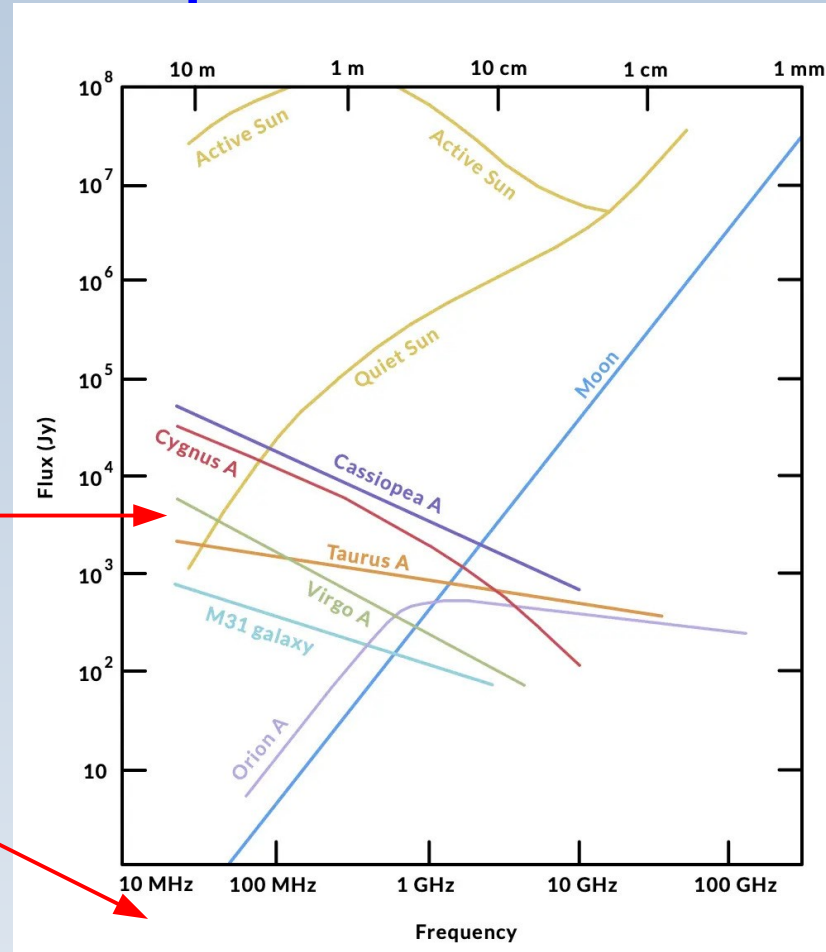
Radio Signals from Space are Weak

Flux density is a measure of signal strength. Units are Jansky (Jy)

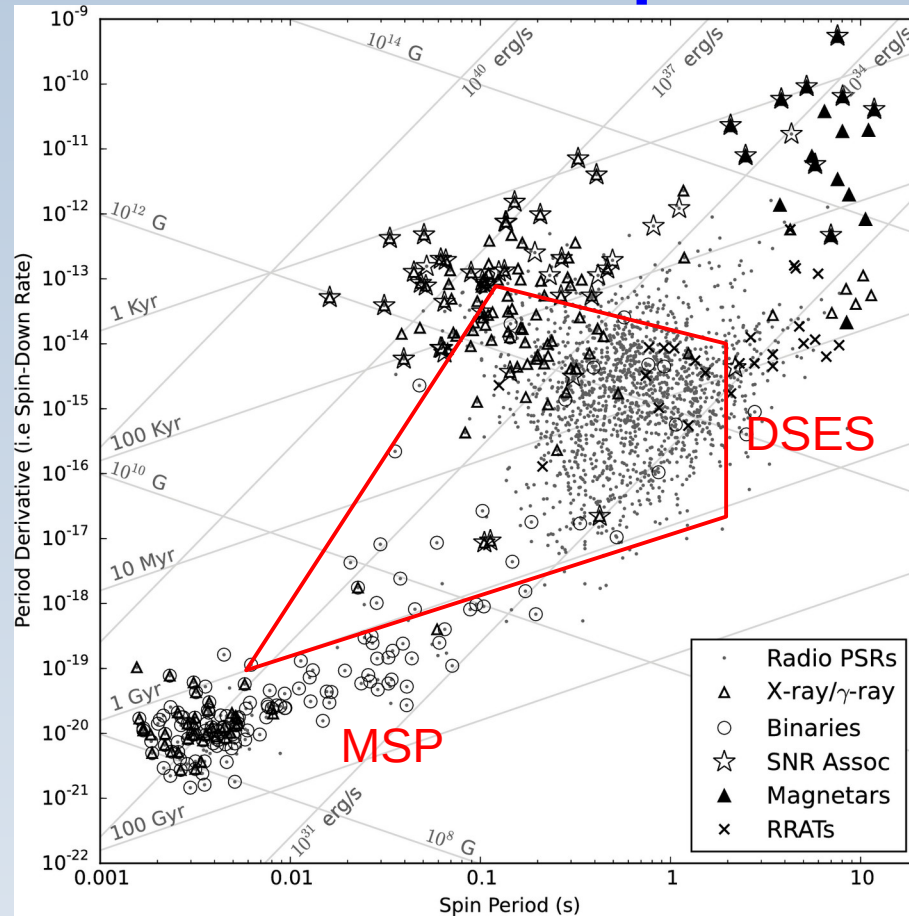
Jy = 10^{-26} watts per meter² per Hertz

Supernova remnants in the middle

Most **pulsars** are in milli-Jansky range.
Pulsars are broadband emitters.



Pulsar Properties from Observed P, \dot{P}

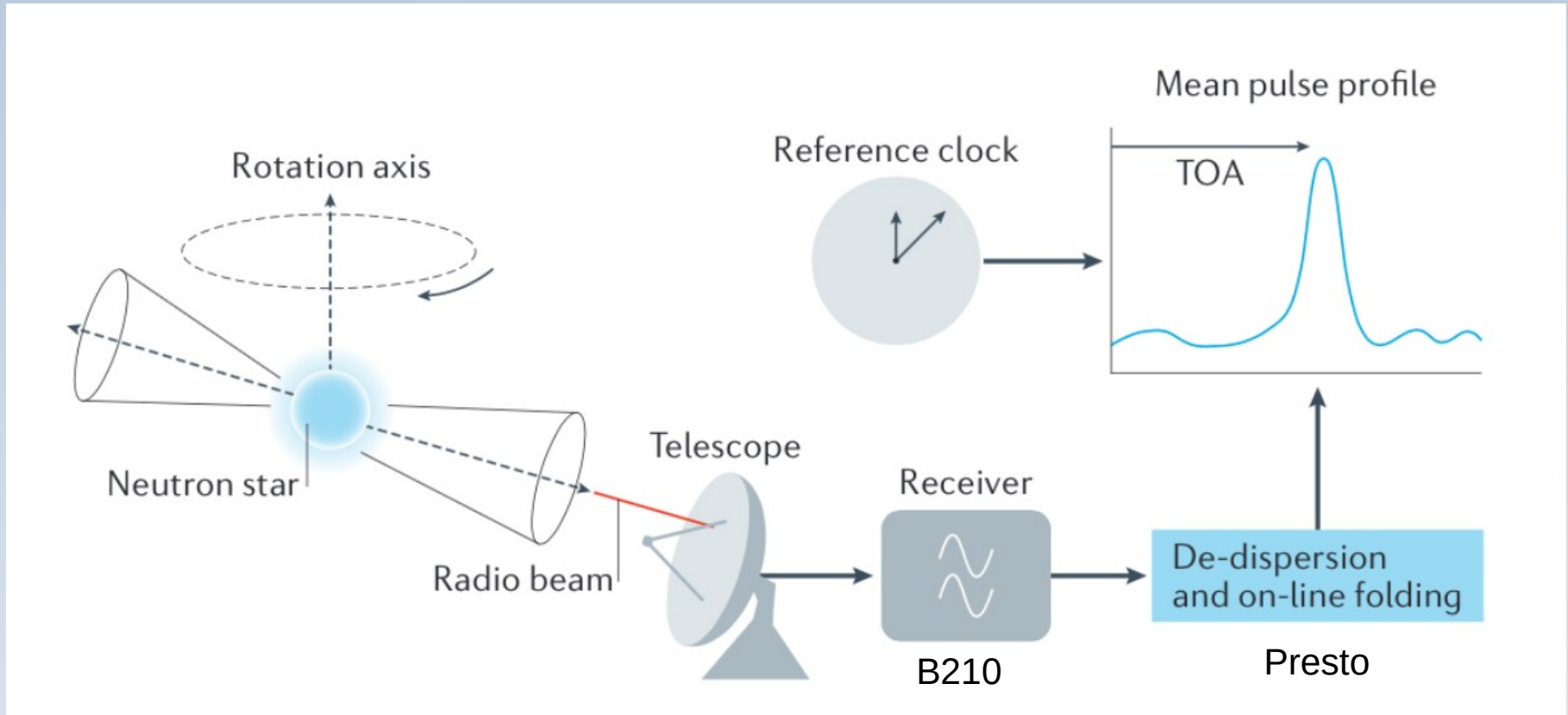


The $P\dot{P}$ diagram shows properties derived from period (P) and period derivative (\dot{P}), including

- Characteristic age (not true age)
- Minimum magnetic field strength
- Spin-down luminosity

Highlighted region is where DSES detects radio pulsars
 $0.005 < P < 1.9$ seconds

Pulsar Detection



Credit: "Handbook of Pulsar Astronomy", Lorimer & Kramer (2005)

Telescope and SDR

- Coordinate feedhorn installation ahead of time
 - Lacking calibration procedures we do bench testing
- Data collection is performed with USRP B210 and GnuRadio via coax feedline from hub
 - GnuRadio generates a filterbank file for post-processing
- System1 Radio Source table contains all pulsars DSES can detect (J2000)





Plishner 60' dish, Haswell, CO
 - Rubidium clock sync
 - 32-core Linux host
 - USRP B210 (56 MHz) SDR

Feedhorn	Pol.	LNA	Filter
408 MHz	Lin.	30 db	90 MHz
1296 MHz	Circ.	30 db	30 MHz
1420 MHz	Circ.	35 db	60 MHz

DSES

System Configuration

Software Tool	Purpose
IONAA Murmur, Stellarium	Plan observations
ATNF database	Ephemeris data (.par)
DSES System 1 Dish Control	Dish pointing and tracking
Spectrum analyzer	Calibrate gain, check RFI
GnuRadio 3.10 filterbank	Data recording (SDR)
PRESTO 4.0 with TEMPO	Pulsar detection
RIPTIDE 0.2.4	Pulsar detection
SIGPROC, watutil, Pint	Misc utilities

DSES Pulsar Catalog

#	PSR Name	First Detection	Period (sec)	Pulse Width (ms)	DM	S400 (mJy)	S1400 (mJy)	Feed horn MHz	Int. Time (min)
1.	B0329+54	09-2020	0.714	6.6	26.7	1500		408	15
2.	B0355+54	07-2022	0.156	3.9	57.4		23	1296	240
3.	J0341+5711	12-2024	1.888	43.0	101.0	364		250	90
4.	J0437-4715	08-2021	0.005	0.1	2.6		150	1420	30
5.	B0531+21	08-2025	0.033	2.0	56.7	550		408	60
6.	B0628-28	07-2022	1.244	63.3	34.4		32	1296	60
7.	B0736-40	06-2022	0.375	22.7	160.9		112	1296	90
8.	B0740-28	09-2020	0.167	4.2	73.7	296		408	30
9.	B0833-45	09-2020	0.089	1.4	67.7	5000		408	15
10.	B0835-41	06-2022	0.752	4.4	147.2		35	1296	90
11.	B0950+08	09-2020	0.253	8.9	2.9	400		408	60
12.	B1133+16	09-2020	1.118	5.9	4.8	257		408	240
13.	B1508+55	09-2020	0.739	10.9	19.6	114		408	60
14.	B1556-44	11-2022	0.257	6.5	55.9		37	1296	180
15.	B1641-45	08-2021	0.455	8.0	478.6		300	1420	30
16.	B1642-03	09-2020	0.388	3.4	35.8	393		408	90
17.	B1749-28	09-2020	0.563	6.1	50.4	1100		408	20
18.	B1859+03	11-2022	0.655	9.0	402.0	165		437	180
19.	B1929+10	09-2020	0.227	5.7	3.2	303		408	90
20.	B1933+16	09-2020	0.359	6.0	158.5	242		408	60
21.	B1946+35	09-2020	0.717	19.3	129.4	145		408	240
22.	B2016+28	09-2020	0.558	14.9	14.2	314		408	90
23.	B2020+28	03-2022	0.343	12.0	24.6		38	1296	180
24.	B2021+51	09-2021	0.529	7.4	22.5		27	1420	30
25.	B2111+46	02-2022	1.014	32.1	141.3		19	1296	90

Frontiers to Explore - 1

- Improved timing, sensitivity: What can we detect?
- Millisecond pulsars (MSP are old, stable, binary)
 - DSES fastest is 5 msec (J0437-4715, binary)
 - Pulsar Timing Arrays (PTA) use MSP to detect GW
- Slow period pulsars
 - Slowest is 1.88 seconds. Use time series algorithm, Riptide. Presto was designed to detect msec pulsars



Frontiers to Explore - 2

- Fainter pulsars
 - Weakest detection is S1400 = 19 mJy (B2111+46)
- Younger or older pulsars (characteristic age)
 - Most DSES detected pulsars are around 10^6 years old
 - From 10^3 (Crab) to 10^9 years (J0437-4715)
- Closer or more distant pulsars
 - $0.16 < \text{Dist} < 7.0$ kpc ($490 < \text{Dist} < 22,831$ light years)
 - $2.6 < \text{DM} < 478.6$ (DM is not distance)

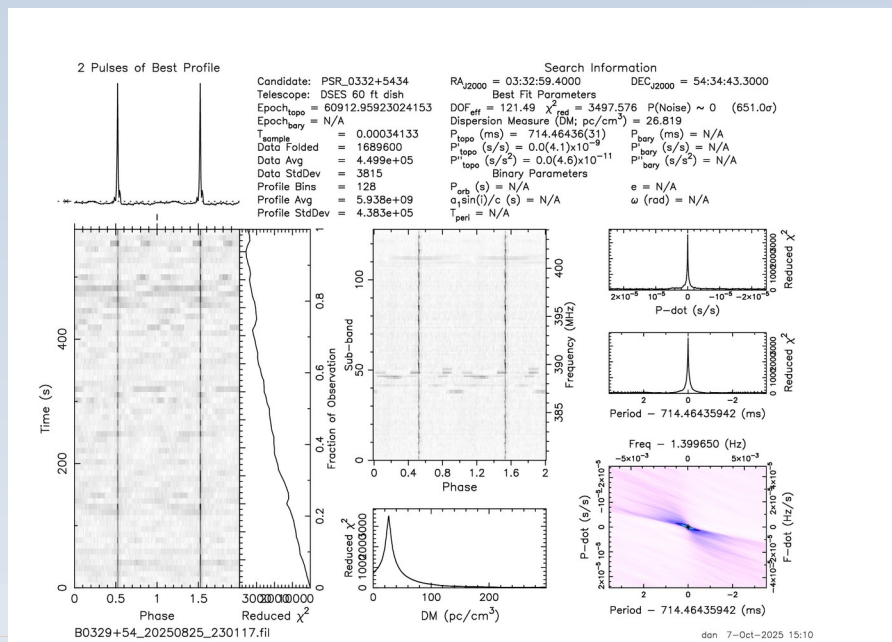
Frontiers to Explore - 3

- Repeat observations of same pulsar:
 - ISM scintillation studies, e.g., B0329+54, B2020+28
 - Analyze 3 types of pulses from Crab (see Aug. 2025)
 - Explore astrophysical causes of timing residuals
 - Pulse Time-of-Arrival (TOA) = absolute time
 - Residuals = observed TOA – modeled TOA
 - Causes include instrument effects, pulsar spin-down, etc.
 - Use Rubidium clock (with offset) to calculate pulse TOA
 - > python get_TOAs.py (install Presto 5.0 to fix numpy lib errors)



Where to Start?

- Lacking calibration procedures, start with a 10 minute collection on B0329+54 (might scintillate)
 - Compare previous collections at same frequency



Plan Obs with Murmur and ATNF

Murmur 22.1.0 24 March 2026 mario.natali@gmail.com http://i0naa.altervista.org

Pulsar mode

Location: Plishner 18m Latitude: 38.3811 Longitude: -103.1560 UTC Time: Wed Apr 22 16:25:53 2026 Local Time: Wed Apr 22 10:25:53 2026

Current Time Zone Name: Mountain Daylight Time (DST)

Buttons: Rev. History, Help, RESET Settings and EXIT, Check for updates, EXIT

System evaluation mode, SET Observation location, LOAD default, CALCULATE

TRACK noise sources, Culminations, Next 24h PSR visibility, Next 24h PSR tracking

CALCULATE Noise Y-Factor, 1 Month PSR visibility, 1 Month PSR tracking

Dish antenna Other antenna

Dish diameter: 18.3 m Dish efficiency: 69 % Frequency: 408 Mhz

Line loss before LNA: 0.1 dB LNA NF: 35.4 K LNA gain: 38 dB

Line loss after LNA: 4 dB Receiver NF: 438.4 K T sky: 4 K T spillover: 10 K

Integration time: 3600 sec. Integration bandwidth: 20000 kHz

User1 User2 User3 Set

Wave length: 0.74 m Effective ant. aperture: 181.4 m² Dish area: 262.89 m² Far field: 911 m Antenna gain: 36.25 dBi HPBW: 10116 arcsec System noise temp.: 57.2 K System noise figure: 0.78 dB G/T ratio: 18.67 dB/K Noise floor: -100.2 dBm SEFD: 871 Jy MDS: 3.24 mJy

SEFD Calculations

List of detectable PULSARS

Check ATNF Catalogue version

PULSARS extracted with S400 flow >0: 734
PULSARS extracted with S1400 flow >0: 2224
PULSARS extracted with S3000 flow >0: 411

ATNF Pulsar catalogue Version: 2.6.5

Sorted by S/N Above horizon

Minimum S/N > 10 S/N >10 suggested for reliable results

Right Ascension (2000) (RA D)	Declination (DEC D)	Pulse width @ 50% of peak (W50)	Barycentric period (P0)	Dispersion Measure (DM)	Flux @ 400 Mhz (S400)	Flux @ 1400 Mhz (S1400)	Flux @ 3000 Mhz (S3000)	Distance (Dist)	Age (age)	Max Int. BW (no de-dispersion)	Expected S/N	Azimuth	Elevation
B0329+54	53.25 deg	6.6 msec	0.71452 sec	26.76 cm ⁻³ pc	1500.0 mJy	203.0 mJy	NA mJy	1.68 kpc	5.53e+06 years	1,020 Khz	4788.3	47.60 deg	47.62 deg
J0341+5711	54.58 deg												
B0531+21													
B1929+10													
B2016+28													
B1933+16													
B2045-16													
B1859+03													
B1818-04													
J2238+6021													
B1911-04													
B1831-03													
B1508+55													
B2111+46													
B2217+47													

Show all PSR List PLAN Observation Select object to track

W50

DM

Flux

BW

Demo

- ATNF Pulsar Catalog
 - <https://www.atnf.csiro.au/research/pulsar/psrcat/>
 - Download psrcat to generate parameters for Presto
- IONAA Murrumbidgee observation prediction
 - <https://ionaa.altervista.org/index.php/downloads>
- Stellarium to verify pulsar track in sky
 - <https://stellarium.org/>

Plishner Dish Location

The screenshot shows the Tac32Plus 2.7.38 software interface. The main display area is divided into several sections:

- Time Display:** A large digital display shows **21:33:27.000**.
- UTC Time from GPS:** UTC Day #107 21:33:27.000, Friday, 17 Apr 2026, GPS Week = 2414, UTC = GPS - 18 seconds.
- PC Time:** 15:33:27.003, Mountain Daylight Time, Latency: 0.
- Sidereal Time:** Local Mean Sidereal Time 04:24:55.40, Greenwich Mean Sidereal Time 11:17:32.94, Modified Julian Day 61147.89823.
- Grid Square:** DM88kj11.
- TIC (usec):** 61.451600.
- GPS Navigation Data:** A table with columns for Latitude, Longitude, Alt(GPS), and Alt(MSL).

	Latitude	Longitude	Alt(GPS)	Alt(MSL)
Cur:	38.3810883°	-103.1564453°	1295.05n	1318.11m
Avg:	38.3810883°	-103.1564453°	1295.05n	1318.11m
Ref:	38.3810884°	-103.1564454°	1295.05n	1318.12m
- Satellites:** A table showing satellite status with columns for PRN, El, Azm, Eb/No, and signal strength bars.

PRN	El	Azm	Eb/No	Signal Strength
15	39 ↑	152	27	GPS
11	11 ↓	82	22	GPS
5	55 ↓	43	28	GPS
21	27 ↓	46	26	GPS
25	20 ↓	211	24	GPS
29	85 ↑	287	32	GPS
18	37 ↑	293	26	GPS
20	40 ↑	116	28	GPS
13	32 ↑	108	25	GPS
26	16 ↑	303	22	GPS
23	23 ↑	228	20	GPS
- Position Hold:** 11 Visible, 11 Tracked.
- Status Bar:** Position Hold, Ant OK, Motorola M12, Rx Only, Bin, 12 ch, V1.0.

A red arrow points to the GPS Navigation Data section.

Comparison Websites

- **DSES** <https://dses.science/science-project-overview/pulsar>
- **K5SO** https://k5so.com/pulsars-detected/pulsars_detected_2.html
- **OE5JFL** <https://qsl.net/oe5jfl/pulsar/pulsar.htm>
- **Neutron Star Group** <https://sites.google.com/view/hawkrao/neutron-star-group>
- **EPN Pulsar Profiles** <https://psrweb.jb.man.ac.uk/epndb/>
- **Green Bank 20m PSC** <https://pulsars.nanograv.org/>

Preparing for Data Collection

- Select candidate pulsar(s) via Murmur
 - Verify track with Stellarium (avoid Sun)
- Each pulsar sub-directory needs .par and .sh
- Use psrcat to make .par parameter file for post-processing
 - `> psrcat -e -psr psr.txt > psrName.par`
 - Verify .par is EPHVER 2, TDB for Tempo
- Edit .sh GnuRadio script parameters (or use GRC)
 - Before pulsar trip: path, pulsar name, RA-DEC, W50
 - At Haswell: gain, center frequency, bandwidth, run time, fbsize

B210
class

GnuRadio Collection Parameters

- Fbsize = # channels. Channel width = bandwidth / fbsize
 - At 1400, DM < 100; Set fbsize so channel width < 0.5 MHz*
 - At 400, DM < 100; Set fbsize so channel width < 0.1 MHz*
 - Check Murmur for max. channel width for each pulsar
- Desired Tsamp ~ 0.1 * W50
 - Based on fbsize, bandwidth, W50, and FFT decimation rate
 - Calculated Tsamp & channel width are printed out at start-up

* “The Handbook of Pulsar Astronomy,” Lorimer and Kramer, 2005, p. 109



Edit Filterbank Parameters in Script

- Run time (seconds)
- Path
- Pulsar name
- RA-DEC
- W50 (sec)
- RF Gain
- Center Freq (MHz)
- SDR bandwidth (MHz)
- Fbsize

- ATNF .par file name

```
runPulsar_B0329+54.sh
/data1/Pulsar/data22/July24/B0329+54

12
13 # Set pulsar filterbank parameters
14 # max 16 char for source. dec = hms. ra = dms.
15 numIter=1
16 single_runtime=3600
17 path='/data1/Pulsar/data22/July24/B0329+54/'
18 sourceN='B0329+54'
19 ra=033259.40
20 dec=543443.30
21 pw50=0.0066
22 rfgain=64
23 freq=1300e06
24 samp_rate=30e06
25 fbsize=512
26
27
28 # prepfold params. Set nCPU = 1/2 total
29 nCPU=2
30 cd $path
31 parFile="${path}J0332+5434.par"
32 if [ ! -s "$parFile" ]
33 then
34     echo "runPulsar error: $parFile not found."
35     exit 1
36 fi
37
```